

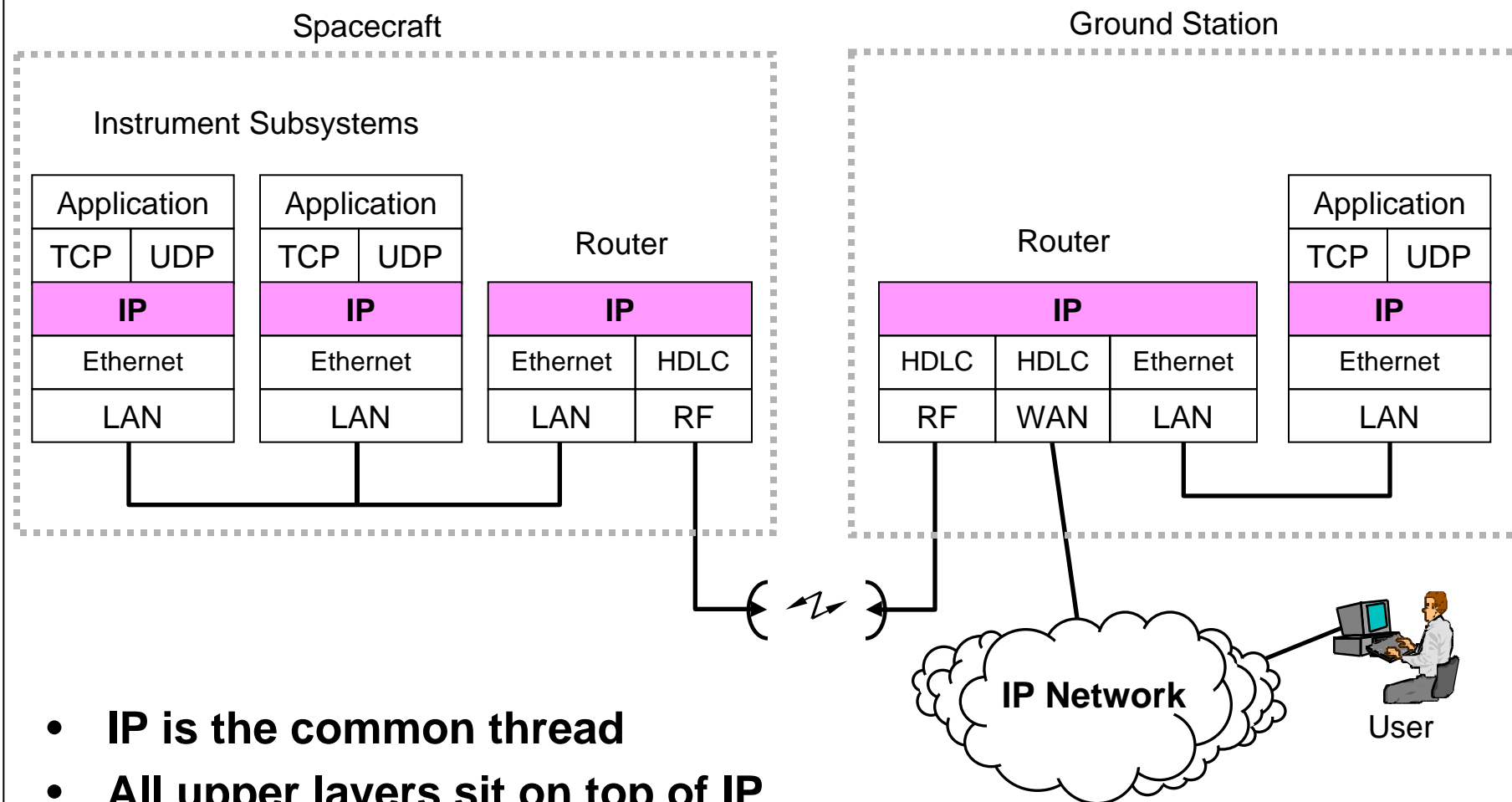
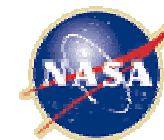


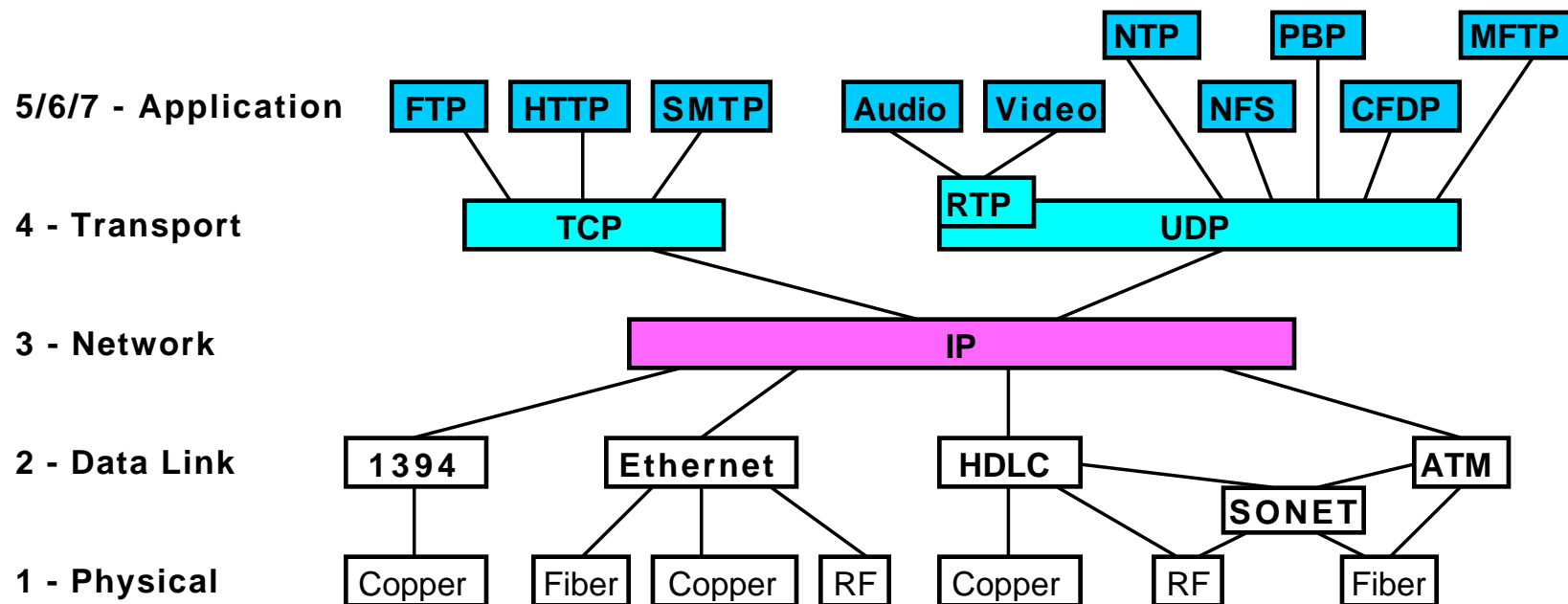
Transport Protocols and Applications for Internet Use in Space

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End-to-End IP Network Concept



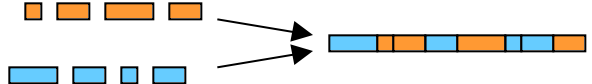


- OSI 7 layer model
- IP is not TCP!
- Paper is on top two layers

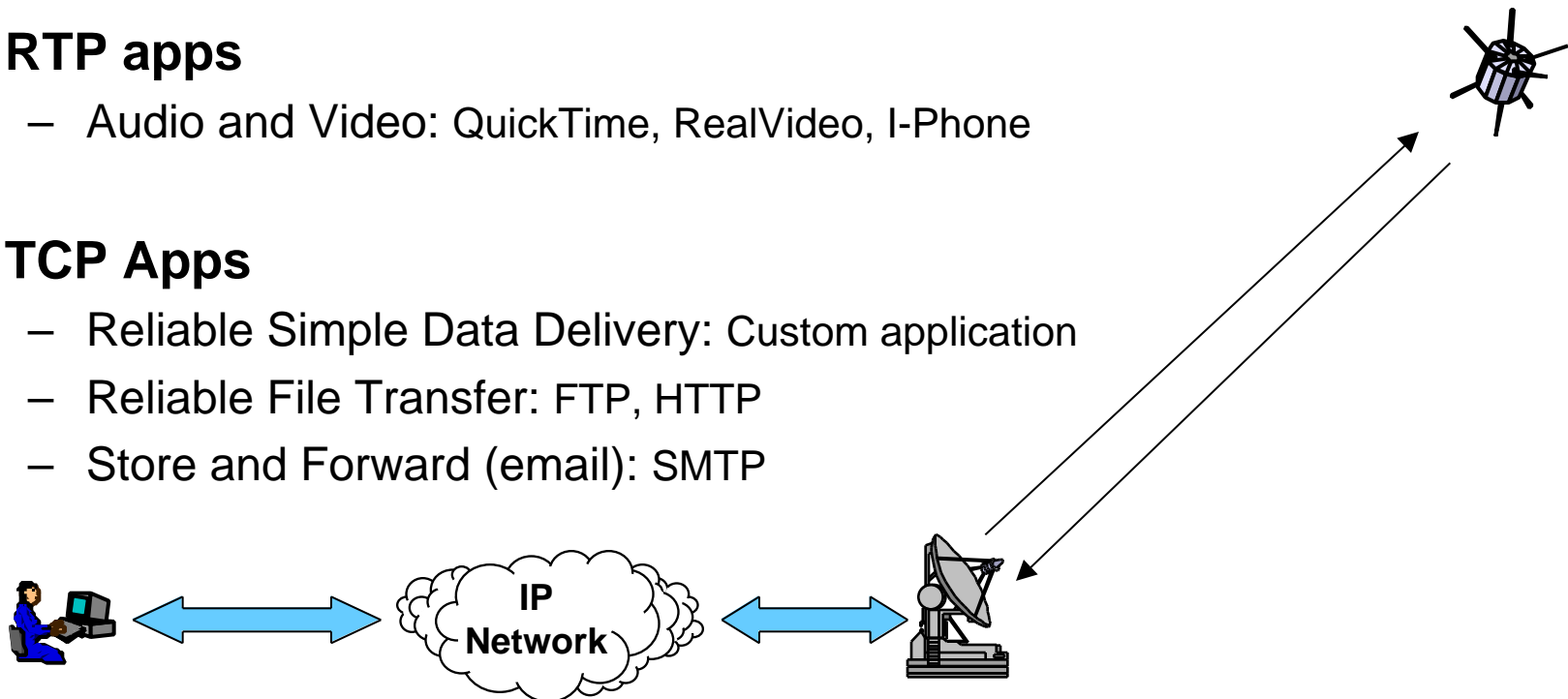


Transport layer



- **Transport layer provides multiplexing** 
- **Three main transport layer protocols on the Internet**
 - UDP - User Datagram Protocol (RFC-768)
 - Provides Multiplexing and error detection (checksum)
 - Atomic packet delivery
 - Delivery and delivery order not guaranteed
 - RTP - Real Time Protocol (RFC-1889)
 - Built “on top of” UDP
 - Adds sequence numbering, timestamping, and delivery monitoring
 - TCP - Transmission Control Protocol (RFC-793)
 - Provides multiplexing, flow control, sequencing, error detection, and automatic retransmission
 - Guaranteed in-order delivery
 - Provides a reliable “byte pipe” from sender to receiver.

- **UDP apps**
 - Simple Data Delivery: Custom application
 - Reliable File Transfer: PBP, MFTP, CFDP, NFS, TFTP
 - Time Synchronization: NTP
- **RTP apps**
 - Audio and Video: QuickTime, RealVideo, I-Phone
- **TCP Apps**
 - Reliable Simple Data Delivery: Custom application
 - Reliable File Transfer: FTP, HTTP
 - Store and Forward (email): SMTP





Space vs Terrestrial Issues



- **Don't Space Links Have Long Delay?**
 - UDP is delay insensitive. Will work to Pluto!
 - LEO is close! 4 - 32 ms Round Trip Time.
 - TCP has been used out to Geosync at over 400 Mbits/sec
- **Aren't Space Links too Noisy for IP?**
 - Only TCP throughput affected by noise. IP & UDP are not.
 - FEC used to improve space link BER. 10^{-5} is spec, 10^{-7} is typical.
 - Uncorrected Telephone lines have a BER of 10^{-5} !
 - ECN, SACK, TCP/PEACH are coming



More Space vs Terrestrial Issues



- **Don't Spacecraft Have Constrained Power, CPU, & Bandwidth?**
 - Compare to an Internet-ready cell phone.
 - New CPUs (StrongArm, PowerPC 750) are ready to fly.
- **Isn't Spacecraft Connectivity too Intermittent and too Variable for IP?**
 - Just like laptop computers, cell phones, automobiles
 - Mobile-IP, DHCP
- **Spacecraft Have Huge Forward/Return Path Asymmetry**
 - Driven by convention, not physics.
 - STDN compatible receivers limited to 4 kbps uplink
 - TDRSS can do 2 mbps symmetric

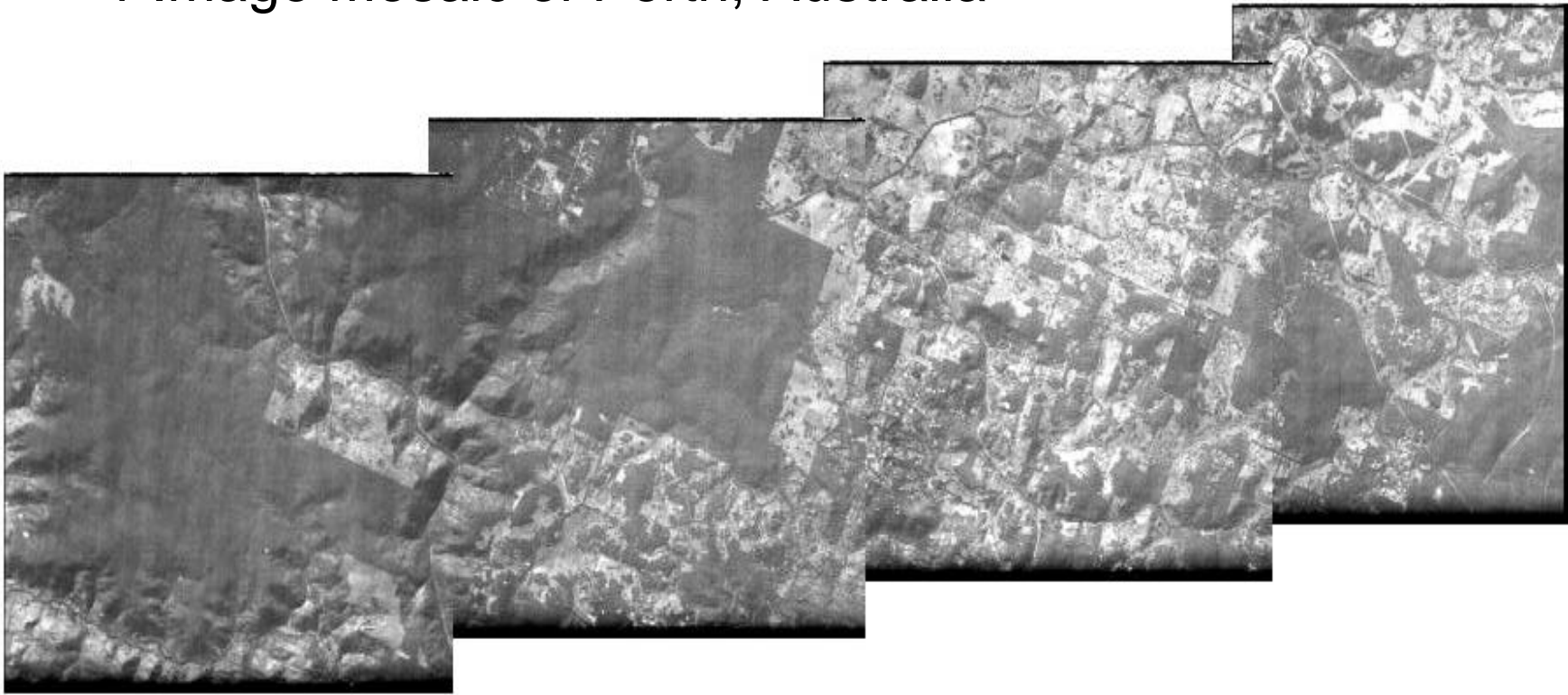


IP Operations Scenarios



- **Real time telemetry**
 - Unidirectional - UDP
 - Reliable - TCP
- **Reliably Downlink Recorded Science & Engineering Data**
 - Short Delay - FTP
 - Long Delay - PBP / MFTP / CFDP
 - Store & Forward - SMTP
- **Onboard Clock Synchronization**
 - Synchronization and drift mitigation - NTP
- **Commanding**
 - Store & Forward - SMTP
 - Reliable Realtime - TCP
 - Blind Realtime - UDP

4-Image Mosaic of Perth, Australia



Error-Free Images Downlinked with FTP
June 7, 2000



Future



- **Ground-based Flatsat Testbed**
 - UDP-based reliable file transfer
 - Mobile IP
 - Mobile Router
 - IPSEC, VPN

- **Flight Validations**
 - UDP-based reliable file transfer
 - Blind Commanding
 - HTTP-based reliable transfer
 - Mobile IP
 - Store & Forward

<http://ipinspace.gsfc.nasa.gov/>